PROGRESS REPORT NO. 10

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THE PROBLEM OF MAN'S GRAVITOINERTIAL FORCE ENVIRONMENT IN SPACE FLIGHT

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By

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Period Covered

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Facilities

Although there has been no increase in number of our major facilities, considerable effort has been expanded in modifying the new Slow Rotation Room to permit long exposure habituation studies with the subjects at right angles to the axis of rotation. This has involved the fabrication of an articulated body mold, an air bearing support frame and minor alterations of the new SRR, some of which are shown in the accompanying photograph.

Tests of the horizontal linear oscillator indicate that an upper limit of the frequency response of this system is about 1 cps with a 2 ft. peak-to-peak amplitude. At the upper range of the frequency response there is nonlinearity in the response-command relationship so that a sinusoidal command signal produces a system response which approximates but is not exactly a sinusoid. It appears that the system is capable of well-controlled sinusoidal oscillation with frequencies up to about 0.5 cps. Further study of command response relationships is in progress.

Personnel

Harlow W. Ades, Head of the Neurological Sciences Division, resigned as of 1 October 1965 to accept a professorship at the University of Illinois. Dr. Ades' research with reference to the vestibular organs, while not carried out under this project and hence not included in these progress reports, will be continued at his new location and close liaison will be maintained.

Professor Bo E. Gernandt will replace Dr. Ades, at least temporarily. Dr. Gernandt, on several occasions, has carried out investigations on vestibular mechanisms at the NAMI and hence is prepared to go on with his work here without delay. Dr. Gernandt is without a peer in the area of vestibular neurophysiology, and his coming is a source of great satisfaction.

Prepublication Notes

Experiments were carried out during Professor Clark's visit last summer which bear on the differential role of, for want of better terms, "contact" and "kinesthetic" sensory inputs influencing the egocentric visual localization of the horizontal (EVLH). By way of background information, it may be pointed out that many investigations have been conducted in which a subject, viewing a dim line of (collimated) light in darkness is required to "set" the line to the horizontal or vertical. The line itself offers an insufficient visual framework on which to base the determination, hence non-visual sensory inputs influence the setting of a visual target which reflects visual spatial orientation. It is not generally appreciated that this simple test procedure, when properly exploited, is indeed an elegant method.

The term oculogravic illusion has been used to describe the apparent motion and displacement of objects in the visual field when a person is subjected to a change in direction

of gravitoinertial force relative to himself such as may be experienced on a centrifuge. This illusion is maximal if the EVLH technique is used but greatly reduced in a lighted room or cubicle with a strong visual framework. The events involved in causing a "maximal illusion" are best made clear by an example. The subject is secured to a fixed seat on a human centrifuge with the center of rotation on his left. He is then required in darkness to set the luminous line to the gravitational horizontal which can be done quite accurately. After closing his eyes he is exposed to a centripetal force of 1.0 G and he feels as if he were being gently tilted "outboard" or to his right until aligned with the new gravitoinertial vertical. This is a "postural illusion" in terms of the physical environment of room and chair but a correct perception in terms of the force environment. On opening his eyes target line will still appear to be rotating clockwise and come to rest in approximate alignment with the gravitoinertial horizontal. That the otolith organs are essential for the correct alignment of the visual target has long been known. Nevertheless, there were inconsistancies which were not easy to explain. Thus, some normal subjects tended to under or overestimate the "setting" in terms of the gravitoinertial horizontal, and some subjects with presumed loss of otolith function, perceived some degree of the illusion and the question arose whether they had some residual otolith function or whether nonotolith cues participated. This was clearly decided in an experiment when subjects without otolith function and normal subjects were exposed to the same change in direction of force in ordinary conditions and when submerged in water. Normal subjects perceived the illusion under water as accurately as in "dry" conditions. The subjects with vestibular defects did not perceive the illusion under water when contact cues were lost, indicating non-functioning otolith organs. Moreover, it proved that the "reduced illusion"they perceived under dry conditions was due to the influence of nonotolithic gravireceptors

The experiment this past summer demonstrated that there were differences among the non-otolith gravireceptors in terms of influencing the EVLH. The investigation consisted in exposing subjects with and without otolith organs to the same change in gravitoinertial force on a centrifuge, once when they were strapped securely into a supporting mold and again when they stood on a platform. In the latter circumstance the contact support was only through the feet, and they maintained different positions of head relative to thorax and trunk relative to legs by muscular bracing.

Normal subjects set the line to the gravitoinertial horizontal much the same in both circumstances; the crucial factor was the position of the head (otoliths) with respect to the resultant force. The subjects with loss of otolith organs set the line quite differently in the two conditions. When standing (kinesthetic cues prominent) their responses were quite similar to normal subjects, but when seated (contact cues) they greatly underestimated the changed direction of the gravitoinertial horizontal; moreover, the position of the head with respect to the force was not a decisive factor.

It is believed that these findings are decisive in demonstrating a hierachy of influences on visual space perception where there is a discrepancy between the visual and force upright; gravireceptor cues will tend to orient the line to the force upright and the otolithic, kinesthetic and contact cues are effective in this order. In normal persons the otolithic cues not only predominate but are the controlling influence; in persons without otolith organs kinesthetic cues are stronger than contact cues. Under conditions of weightlessness, with physiological deafferentation of the otoliths, the roles of contact and kinesthetic inputs may be greatly enhanced. Moreover, individuals vary either with respect to the relative contribution of different sensory inputs or to their relative significance for visual space perception. It is hoped that extension of these studies will explain certain curious findings both in normal persons and in persons with vestibular defects.

A number of studies have been carried out by Dr. Fregly which at once indicate the usefulness of our new ataxia test and contribute to our understanding of postural mechanisms. One study dealt with the influence of alcohol on the postural equilibrium (ataxia) test performances of bilateral vestibular labyrinthine defective individuals. Significant performance decrements were found on the compensable (visually enhanced) vestibular ataxia test performances but no decrements were evidenced on the non-compensable (non-visual) vestibular ataxia test performances in all subjects except one with outstandingly superior proprioceptive sensitivity.

A comparison of postural equilibrium (ataxia) test performance capabilities between normals, blindfolded normals, bilateral vestibular labyrinthine defectives, partially blind, totally blind, and streptomycin-treated individuals with Meniere's disease was carried out. Initial and highly practiced test scores indicated significant between group differences, and more severe limitations upon improved performance capabilities were evidenced in the vestibular defectives on the non-visual tests and in the totally blind subjects on the tests which were designed (for normal subjects) to be performed with eyes open.

The non-vestibular contributions to postural equilibrium functions in normal persons. In a large group (N = 500) of non-experienced and highly experienced present and former naval aviators in the age range of 42-53 years longitudinally examined (at 5-year intervals since 1940) for cardiovascular and related problems, a number of physical health status variables were found to be significantly correlated with postural equilibrium test performances, notably somatotypes, blood pressure, heart rate, smoking, weight, and age.

Dr. Niven and Mr. Hixson are continuing their studies on the frequency response of the human semicircular canals. Previous work has been directed toward the development of a mathematical model of semicircular canal function in terms of its performance characteristics in response to dynamic stimuli and the development of experimental techniques to obtain them. Performance data on phase lag of the cupula as a function of frequency have been reported. However, as a recent evaluation of this work in vestibular control systems (NASA N6510363) stated, "Detailed experiments of this type at a wide range of frequencies would be very helpful in detailed resolution of the amplitude and phase versus frequency

characteristics of the cupula." Such experiments are underway on a continuing basis and data is being collected over an extended frequency range and measurements of amplitude as well as phase are being made. These studies are in the data collection and analysis phase.

These investigators in collaboration with Dr. Correia are studying vestibular related responses associated with periodic linear acceleration stimulus. Most studies of the human otolith organ have used static stimuli presented in the frontal plane of the head because the evoked responses could be recorded and quantified most readily. The current experiment involves the extension of the stimuli from static to dynamic form and the exploration of the response capabilities of the receptor to stimuli presented along all three axes using the Coriolis Acceleration Platform (CAP) to produce the desired stimulus conditions. Importantly, nystagmus has been found to be elicited by sinusoidal linear acceleration stimuli. Subjective observations of visual target movement and of postural sensations are also correlated with the stimulus. A report is under preparation.

The same investigators are preparing a tangent model of otolith stimulus-response relationships. Man's responses and orientation in linear force environments require elucidation because of potential implications for their performance in aircraft operations and space flight. In general, body sensations of tilt, the adjustment of visual targets to the horizon or vertical, and other such indicators of orientation have been considered closely proportional to the direction of the resultant linear acceleration vector acting through the body with the observation that a magnitude effect does exist. In a report now in its final draft stages, data are presented on the effects of the stimulus vector magnitude independent of its direction for a selected series of direction angles. A mathematical model of otolith response which is comprehensive enough to describe not only the present data but also data from related studies in the literature is formulated.

Completed Reports

* 90. Graybiel, A., Schuknecht, H. F., Fregly, A. R., Miller, E. F., II, and McLeod, M. E., Long term follow-up in Meniere's cases treated with streptomycin sulfate.

91. Igarashi, M., Otolithic membrane - Its morphology and some functional considerations.

92. Ambler, R. K., and Guedry, F. E., Jr., The validity of a brief vestibular disorientation test in screening pilot trainees.

93. Guedry, F. E., Jr., Orientation of the rotation-axis relative to gravity: Its influence on nystagmus and the sensation of rotation.

94. Lansberg, M. P., Guedry, F. E., Jr., and Graybiel, A., The effect of changing the resultant linear acceleration relative to the subject on nystagmus generated by angular acceleration.

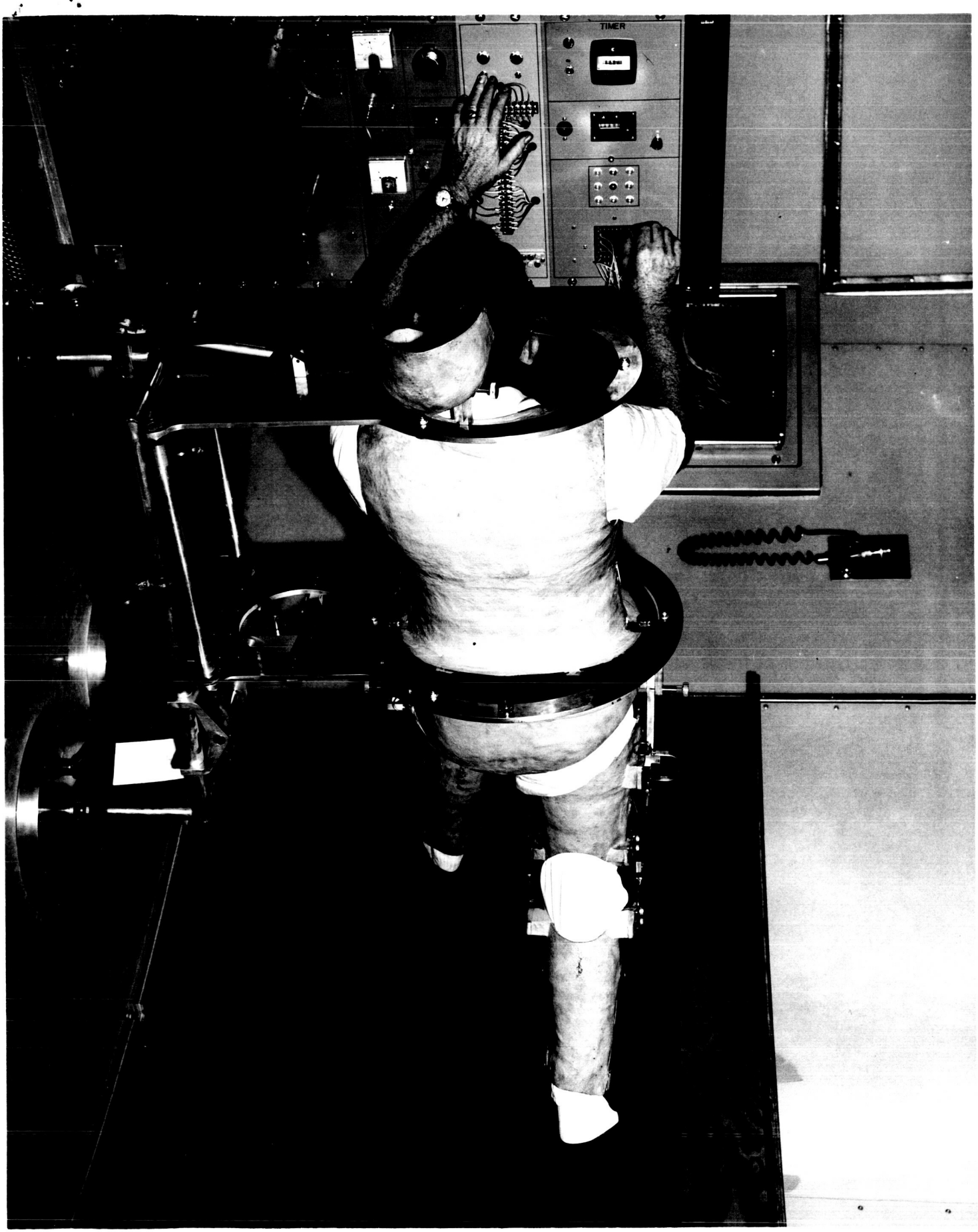
95. Guedry, F. E., Jr., Sensory mechanisms concerned in spatial orientation.

96. Miller, E. F., II, Fregly, A. R., van den Brink, G., and Graybiel, A., Visual localization of the horizontal as a function of body tilt up to $\pm 90^{\circ}$ from gravitational vertical.

97. Miller, E. F., II, Graybiel, A., and Kellogg, R. S., Otolith organ activity within earth standard, one-half standard, and zero gravity environments.

98. Wood, C. D., Graybiel, A., and Kennedy R. S., A comparison of effectiveness of some antimotion sickness drugs using recommended and larger than recommended doses as tested in the Slow Rotation Room.

*Serial numbers.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